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# THE PROBLEM OF MARINE BIOLOGY.

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In common with the other branches of biological science, the study of marine life has made wonderful advances in the past half century, and we now begin to get a proper conception of the vastness and importance of this realm of nature.

The study of marine life has been compassed by serious difficulties; on shipboard it is impossible to examine in the living condition the enormous quantity and endless variety of forms brought up at a single haul of the net or dredge; and the old method of merely dropping the specimens into vials of alcohol resulted in vials of wrath to the naturalist who later studied the creatures in hopes of gaining from the distorted relics some knowledge of the normal appearance and anatomy. Now all this is changed, and by aid of certain chemical reagents most animals can be killed and preserved in a manner very satisfactory for study of their gross and microscopical anatomy, and hence the material collected can be examined at leisure in permanent laboratories with results corresponding to the better facilities. There has, too, been a great lack of suitable and accurate collecting apparatus. The early method was to scoop up a quantity of sea water and then tediously examine it in small quantities under the microscope. In 1845 Johannes Müller, the great pioneer of marine biology, conceived the idea of condensing into a small volume of water

the forms which would be found in a very great area. This resulted in the invention of the "Müller Net," a small gauze net which is drawn through the water, entangling in its meshes the very minute and delicate organisms. For a long time Müller and his students pursued the study of marine forms, and at length came the discovery that the marine fauna and flora was directly comparable to the terrestrial.

Yet little is known of the laws of the distribution of marine life. The laws of the distribution of the terrestrial fauna and flora have been formulated for animals in the classical works of Wallace and for plants by Griesbach. The famous "Challenger" expedition (1873–1876), under the direction of Sir Wyville Thompson and Dr. John Murray has given us the largest conception of the wealth of marine life, and has laid the foundations for the study of the marine forms both at the surface and in the depths of the ocean. Dr. Murray in his preliminary report called particular attention to the enormous wealth of organic life not only at the surface, but also many hundred fathoms below. He says that when living forms were scarce on the surface the tow net usually disclosed very numerous forms below, even to a depth of 1000 fathoms or more. In the North Pacific Ocean the discovery was made that zones of definite depth are characterized by animals and plants peculiar to them. The tow nets sunk to 500, 1000 or 2000 fathoms brought up forms never found within 100 fathoms of the surface. The animals characteristic of these different depths are, for the most part, of the class of Radiolorians, those microscopic organisms whose silicous skeletons form much of the soft ooze which carpets the bottom of the deep sea. Prof. Haeckel, by study of this material was led, in his monumental work on the Radiolaria, which forms a part of the "Report of the Challenger," to the recognition of three groups, (*a*) pelagic, swimming at the surface of the calm sea; (*b*) zonary, swimming in definite zones of depth (to a depth of more than 20,000 feet); (*c*) profound (or abyssal) animals swimming immediately over the bottom of the deep sea. In general the different characteristic forms correspond to the different zones (up to 27,000 feet).

The existence of this intermediate pelagic fauna was called in question by Alexander Agassiz, on the ground of the liability of error in using the ordinary open net instead of one which could be closed at a definite depth and then drawn up; and more particularly upon the ground of his own experiments made in 1878 on the "Blake" expedition. He believes that the great bulk of the ocean contains no organic life at all, that the surface fauna of the sea is limited to a relatively thin layer, and that there is no intermediate layer, so to speak, of animal life between the fauna of the bottom of the deep sea and of the surface.

Agassiz's results are contradicted by those of Chierchia on the Italian corvette "Vettor Pisani." With the closable net invented by Palumko he brought up an astonishing quantity and variety of forms of life from different depths, even up to 4000 meters. Prof. Carl Chun, with an improved closable net, studied the marine fauna and flora of the Gulf of Naples. He formulates his results as follows: 1. That part of the Mediterranean investigated shows a rich pelagic life even to a depth of 1400 meters, as well as at the surface. 2. Pelagic animals, which during the winter and spring appear at the surface, at the beginning of summer seek the depths. 3. At greater depths pelagic animals occur, which hitherto have seldom or not at all been observed at the surface. 4. A number of pelagic animals during the summer remain at the surface and never go into the depths. From his observations upon the vertical distribution of marine life he was led to remark that the surface fauna was apparently only the advance guard of the vast army below. His conclusions were confirmed by observations made during a trip to the Canary Islands, and agree with those made by Prof. Haeckel twenty years before.

Prof. Hensen, of Kiel, has for several years past been studying the phenomena of pelagic life with a view of ascertaining its relations to the fisheries question. He has proposed the term Plankton (from πλάνομαι, to wander) to designate this world of marine life. Prof. Haeckel agrees with this and adds Planktology, that branch of biology which deals with the study of the Plankton. Prof. Hensen hopes to gain val-

uable information upon the phenomena of marine life by a careful mathematical estimation of the number of individuals in a given bulk of water. Presumably from this and other data some knowledge may be gained of the quantity of life which any definite area of the sea is capable of sustaining.

Prof. Ernst Haeckel, of Jena, has lately published an admirable resumé of our knowledge of pelagic life, and has made a very distinct advance by formulating some of the laws which govern its distribution. He has probably done more than any one man to advance our knowledge on this line. Ever since 1854, when, as he tells us, he accompanied the great Johannes Müller to Heligoland and was there introduced by his master to the marine wonderland, he has almost continuously pursued the study of the Plankton. He believes that aquatic life in its broadest features shows conditions of distribution similar to those of terrestrial life, and that we may for the former as well as for the latter distinguish five great geographical provinces, each represented by characteristic forms of animals and plants. 1. The Arctic Ocean. 2. The Atlantic. 3. The Indian. 4. The Pacific. 5. The Antarctic.

All aquatic organic forms fall into two great divisions. 1. Those which live free in the water, either swimming actively or passively floating at the mercy of currents and winds. These compose the Plankton. The Plankton thus includes the widest range of organic size and form, from the minutest microscopic organisms to the gigantic cetaceans. 2. Those forms which live upon the sea bottom, either fixed or creeping about. To these the term Benthos (τό βένθος, the bottom of the ocean) is applied. The variety of forms living near the shore is known to vary with the depth, while the forms characteristic of the comparatively shallow waters of the coasts are widely different from those which inhabit the bottom of the deep sea.

The number and the kind of forms composing the Plankton are found to differ with the quality of the water, *i. e.* fresh or salt. In the ocean there is a marked difference which is conditioned by the distance from the shores, either of continents or islands. There are many species of animals, particu-

larly certain coelenterates, echinoderms and worms, which pass only part of their life as free swimming animals; for the remainder they are bottom dwellers. Such species are not usually found far from the coast, and hence the true oceanic Plankton is made up of forms which pass their entire life as free swimming organisms. By the presence or absence of these bottom dwelling species the Planktologist can determine approximately the region where the forms were captured.

A mere list of the genera, not to mention the species of plants and animals up to the present found to take part in the constitution of the Plankton would be very formidable. The range in size is enormous; from the exceedingly minute unicellular algae $\frac{1}{25000}$ of an inch in diameter to the huge bulk of many fishes and cetaceans. The microscopic forms constitute the fundamental food supply in the cycle of marine life. They are capable of exceedingly rapid multiplication, and furnish nourishment for the myriads of large animals, which in time are preyed upon by the still higher forms. The inconceivable number of individuals of the smaller species is demonstrated by Prof. Hensen's determination of the number of individuals in about two cubic yards of Baltic Sea water. This was found to contain 5,700,000 distinct organisms; of these only about 150,000 were visible to the unaided eye. But very often microscopic forms become so numerous as to form a slime upon the surface of the water for a considerable area. Ships frequently sail for miles through water colored by these microscopic organisms, *e. g.* the so-called "black water" of the Arctic and Antarctic Seas, is a slime of diatoms, which serve as food for the shoals of minute crustacea and mollusca (Pteropods, sea butterflies, and Cephalopods, squid, cuttlefish) upon which the walrus and whales feed. In the warm regions the inconceivably enormous quantity of diatoms are replaced by another kind of algæ, the Oscillatoriæ, which often for an area many miles in extent color the sea a dark red or yellowish brown. The Red Sea received its name from the abundance of one of these algæ, *Trichodesmium erythræum,* which, according to Ehrenberg, colored the water along the shore a blood red. In the warm region also are

found the huge floating banks of Sargassum, or gulfweed, forming the so-called Sargasso Seas of the Atlantic and Pacific Oceans. These areas are found to have a marine fauna and flora peculiar to themselves, but approximating in character to that of the coast waters.

The simplest forms of animal life of the Plankton belong to the groups of Infusoria and Rhizopods; to the latter belong those minute animals, the Foraminifera and Radiolarians, which occur in such enormous quantities that their calcareous and siliceous shells form the "deep sea ooze" which carpets the bottom of the deep sea. It is the shells of these animals too, which have built the vast chalk beds in various parts of the world. Among the multicellular animals which take a prominent part in this marine world are many species of medusæ (jelly fish) and the closely related Siphonophores, of which the beautiful Portuguese man-o'-war is the most familiar representative. The class of worms is represented by many free-swimming species; but in the number of individuals it is far surpassed by the molluscs, chiefly represented by the squids, the pearly and paper nautilus, and the huge cuttlefish, and by the minute and delicately beautiful sea butterflies (Pteropods), which occur in vast schools in the polar seas. Often too, in very considerable number are found the free-swimming larvæ of Echinoderms, as also many worm larvæ, which, like the former, pass their adult life upon the bottom. Every haul of the gauze net is certain to contain some representatives of the great class of Crustacea, often great numbers of species, as well as of individuals. In distribution these seem to be subject to pretty definite laws, and a careful study of the phenomena would be of great interest. There are found also certain Tunicates, a group interesting because many investigators believe that here we find the transition from the invertebrate ancestor to the higher plane of life of which man is at present the highest representative.

The vertebrates of the Plankton embrace the great group of fishes, and in addition the marine birds, the seals and walrus, and finally the cetaceans. In this connection, too, the enormous number of fish eggs floating at the surface of the ocean,

as well as the transparent, newly-hatched fry must be mentioned. Prof. Hensen hopes to get an idea of the approximate number of fish of a given species in a certain area, computing the number of eggs and fry of that species within that area.

The phenomenon of marine phosphorescence is very widely known with admiration and wonder. Its cause is chiefly or solely bound up with organic life. The majority of pelagic animals display the phosphorescent light in different degrees. In some the entire living animal is brighly luminous; in other the light is limited to special organs. But much of the phosphorescence of the ocean appears to be caused by the fragments of dead organisms, and is connected with the presence of bacteria.

Since many chlorophyll-bearing organisms are found at depths unpenetrated by sunlight it has been suggested that the light necessary for their growth is furnished by the phosphorescent organisms.

The composition of the Plankton is exceedingly irregular, both in qualitative and in quantitative relations; its distribution in the ocean is also very irregular, both in time and in place. The variations occur near the shore as well as far out at sea. Very often the greater part of the mass of Plankton is made up of organisms belonging to a single group. Sometimes unicellular algæ make up nearly the whole bulk, at another medusæ, siphonophores or ctenophores; indeed, almost any group of marine organisms may occur in such quantities as to compose more than one-half of the total bulk of the Plankton, at that time and place. The fundamental causes of variation in the quantity and quality of the Plankton appears to be conditioned by time, climate and currents.

*Temporal Differences.*—For a satisfactory determination of these more complete observations are needed. Reliable data can be furnished by the observations at the numerous marine laboratories and zoological stations now springing up in different parts of the world. The causes which underlie these yearly, monthly, daily and hourly variations are manifold; in part meteorological, in part biological. They are comparable

to the corresponding oscillations of the terrestrial fauna and flora, and depend on the one side upon climatic and meteorological conditions, and on the other upon the varying mode of life, particularly upon conditions of reproduction and development. Just as the annual development of most land plants is bound up with a definite time of year, as the time of budding and leafing, of blooming and fruiting, have in the "struggle for existence" become adapted to the meteorological conditions, the time of year and other conditions of existence, so too the annual development of most marine animals is conditioned by definite habits, which have become fixed by heredity. The yearly variations may be compared to the good and bad fruit years. This yearly variation has been noted by many observers in case of many marine animals. Our attention is often called to an example of it in the unusual abundance or scarcity of the catch of certain food fishes.

Many marine animals, particularly certain medusæ, siphonophores, ctenophores, molluscs and tunicates, are found at the surface only periodically, in one or a few months of the year. This is probably dependent upon conditions of reproduction and development, as well as upon the temperature of the season. The daily variations are conditioned by the weather and particularly by the wind and rain. A shower will very quickly reduce the specific gravity of the surface water and thus drive the surface dwelling animals below. Many animals rise to the surface only at a definite time of day, some in the morning, others at noon, and yet others only towards evening.

*Climatic Difference.*—Prof. Haeckel thinks that the quantity of the Plankton is very little dependent upon the climatic difference of the zones, but that the quality is greatly so, and indeed in this way, that the number of component species diminishes from the equator to the poles. These conditions, he believes, are directly referable to the influence of the sun, "the omnipotent creator," whose more direct rays bring about an acceleration in the processes which make up the cycle of life. As this is true of the terrestrial fauna and flora so it is true of the marine.

*Currentic Differences.* — Conspicuous differences are also brought about by the numberless currents, great and small, by the little-known deep sea oceanic currents as well as by the better-known great surface currents, the Gulf stream, the Falkland stream, the Guinea stream and others. These currents play a great rôle in the distribution of many forms of life. More local influences are exerted by the small currents whose causes are found in the climatic and geographical conditions of the adjacent coast. The relations of Plankton life to currents is little known, and needs investigation, but first a better knowledge of the currents themselves is necessary.

Almost everyone who has seen the surface of the ocean in a calm has noticed the glassy areas of irregular shape. These are found on the high seas as well as in sheltered bays and harbors, and are of very special interest to the student of marine life. So far as made out they are extremely irregular in time and place of appearance, and the conditions governing them have not been carefully studied. They are in a measure influenced by winds and currents, by the ebb and flow of the tide. Here, into a limited space, are crowded great numbers of organic forms; this space is readily distinguished from the surrounding water in which there is comparatively little life. These phenomena have been noticed by seafaring men and have many different names in different countries.

A word in conclusion as to the bearing and importance of the Plankton in human economy in the near future. When Malthus promulgated his famous doctrine he failed to consider the final element which enters into the problem of human population, the human mind. The ingenuity of the human mind has brought about a decreased efficiency in the natural checks to undue increase, and thus an artificial increase in the food supply is rendered necessary for the crowding population. This food supply is now mainly derived from the cultivation of the land. A still further increase of population will necessitate a levy upon marine life. As soon as man to any great degree becomes a factor in the Plankton conditions by drawing from it large quantities of food, particularly in the form of mature animals, the equilibrium of oceanic life

will be disturbed, and must be adjusted by artificial means. But further, a study of the phenomena of marine life shows that the water as well as the land, through cultivation, is capable of producing a greatly increased food supply for man. The necessity of cultivating the marine resources is even now apparent, and many governments have already begun to cope with the question by the establishment of commissions of fisheries. Of these commissions that of the United States stands in the front rank by virtue of its positive results. But in the near future individual attention must be turned to supplementing the terrestrial resources, the wheat fields, the cattle and sheep ranches, by an increasing utilization and development of the possibilities of marine farming; by fish propagation, by plantations of oysters, clams, quahaugs and scallops, by raising herds of lobsters and crabs. Improved breed of fish, of lobsters will result. The possibilities are well-nigh limitless; and by cultivation of the sea and sea bottom as well as of the land, man will postpone indefinitely the fulfillment of the Malthusian prophecy.

But conditioning all advance in the possibilities of marine cultivation is the knowledge of the Plankton, of its distribution, and of the fundamental basis of marine life, the microscopic marine organisms in the ocean.